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Assessment on Medowo Village Kandangan District, Kediri Regency as Biogas Based Energy Independent Village

Wahyu Devi Hapsari Wijayanti[1*], Surjono[2], Hartati Kartikaningsih[3]

[1] Master Student of Environmental Resource Management and Development, Sekolah Pascasarjana,Universitas Brawijaya, Malang, Indonesia.
[2] Lecturer of Urban and Regional Planning, Universitas Brawijaya, Malang, Indonesia.
[3] Lecturer of Environmental Resource Management and Development, Sekolah Pascasarjana, Universitas Brawijaya, Malang, Indonesia.

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Corresponding Author:
Wahyu Devi Hapsari Wijayanti
wahyu.devi09@gmail.com

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Abstract: National energy security can be achieved by improving energy security at the village scale. Village energy independence can be achieved if at least 60% of the village's energy needs can be met by utilizing local energy potential. To determine the energy independence of a village, it is necessary to collect data on total energy usage and the potential generation of existing energy source. Medowo Village was chosen as a case study because this village actively use biogas as energy source for cooking. This study was conducted using a mixed method approach with an explanatory sequential design type. The descriptive method is used to describe the condition of energy supply in Medowo Village. The quantitative method is used to determine the condition of supply-demand and the potential for biogas generation. Primary data collection was carried out through questionnaires and direct observation at the location. Meanwhile, secondary data collection was obtained from literature studies, KUD Kertajaya, and related government agencies. It was found from the study that current biogas production only reach 40.31% of the theoretical biogas production potential. As for total energy mix, biogas contribution is 15,37%. Therefore alternatives are offered to achieve energy independence by paying attention to problems encountered during research.

Keywords: Biogas; Energy independent village; Potential assessment; Renewable energy; Supply-demand

Introduction

The Indonesian government continues to strive to achieve national energy security as mandated in Law Number 30 of 2007 concerning Energy. Given Indonesia's geographical conditions as an archipelagic country, one of the challenges of the national energy security improvement program is how to ensure that people living in rural areas and remote, outermost, and remote areas (3T) can access energy as easily as people living in urban areas (Soraya & Hasjanah, 2024). Villages are of concern because they are considered to have a major role in efforts to increase national energy security (Wirawan & Gultom, 2021). Based on Minister of Home Affairs Decree Number 050-145 of 2022, the number of villages throughout Indonesia in 2021 was 74,961 and was home to almost 65% of the Indonesian population. Hence increasing energy security in rural areas will also increase national energy security. In this regard, to encourage the realization of energy security on a rural scale, the Ministry of Energy and Mineral Resources as an extension of the Indonesian government introduced the Energy Independent Village program in 2007(ESDM, 2009; Purwono et al., 2013). Ministry of Energy and Mineral Resources Regulation Number 25 of 2013 categorizes villages that are able to meet at least 60% of their own energy needs by utilizing local energy potential as Independent Energy Villages.

One of the villages that has great potential to be developed into an energy independent village is

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Medowo Village, located in Kandangan District, Kediri Regency, East Java Province. This village is located on the border between Jombang Regency and Kediri Regency, which is on the slopes of Mount Anjasmoro. This village has a long history of using renewable energy sources, starting in 1985 with the use of micro-hydro to produce electricity. Furthermore, in 2000, several of the village community received rooftopPV to generate electricity. In 2006, with assistance from Hivos, the Ministry of Energy and Mineral Resources, and PT. Nestle, the people of Medowo Village are starting to use a biogas digester based on dairy farm waste to produce fuel for cooking activities. Along the way, microhydro and rooftop PV have stopped operating. Meanwhile, biogas digesters are still operating, and currently the number has reached 300 units. With the history of using renewable energy conversion technology, Medowo Village has the potential to obtain the title of Independent Energy Village if the renewable energy produced can reach 60% of the village's energy mix.

So far, the energy independence of a village has always been self-declared. Villages that utilize renewable energy are generally considered energy independent villages. In fact, if referring to the description of the Energy Independent Village of the Ministry of Energy and Mineral Resources, to obtain the title of energy independent village, the portion of renewable energy in the energy mix must reach at least 60%. Previous studies related to Energy Independent Villages generally measure the potential capacity of energy supply owned by the village based on one type of energy used, for example, energy for cooking only or electricity only. Zainur-Ridlo (2019) analyzing the independence of electrical energy in Sasiil Village, Sapeken District, Sumenep Regency through modeling of hybrid off-grid energy generation (wind and solar) using HOMER Energy Modeling software. Batistuta et al. (2021) using analyzing the sustainability of biogas-based Energy Independent Villages using the Multi Dimensional Scaling (MDS) method. From these studies, it was not specifically measured whether the village had entered the category of Energy Independent Village or not. Therefore, this study conducted an analysis of all types of energy demand in Medowo Village. Then it was confirmed whether the portion of renewable energy in total energy mix had reached 60%. Assessment on Medowo Village can be used as a benchmark to track the progress of energy independent villages development. In addition to tracking the progress of energy independence, this study also confirms other benefits obtained from the energy independent village program in Medowo Village as well as the advantages and disadvantages of each renewable energy conversion technology which was once used in Medowo village.

Method

Data Collecting

The research approach method used in this study is a mixed method approach with an explanatory sequential design type. According to Sugiyono (2020) in research with an explanatory sequential design type, after quantitative data collection was carried out, qualitative data collection was carried out to deepen understanding of the problems being studied. The flow of this research is as shown in Figure 1. In this study, the quantitative method is used to determine the conditions of energy demand and supply and the potential for renewable energy generation in the development of Medowo Village as an Energy Independent Village.

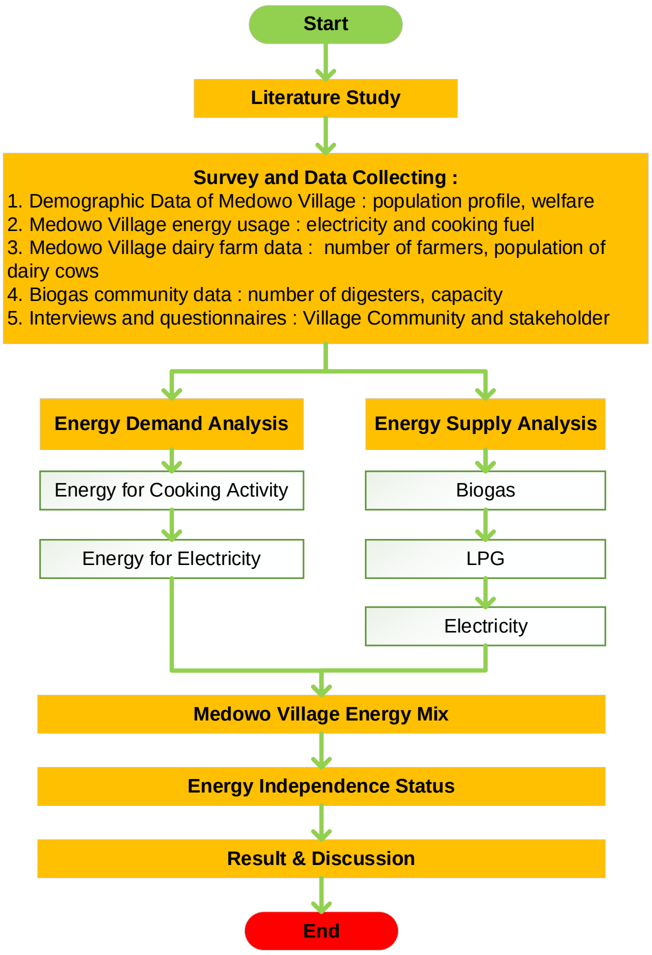

Figure 1. Flowchart

While qualitative research is a research method based on post-positivism or interpretive, which is used to research natural object conditions without engineering with researchers as key instruments. Qualitative method data collection techniques are carried out by triangulation or a combination of observation, interviews, and documentation. In this study, the qualitative method is used to explain what factors influence the selection of renewable energy sources used by the residents of Medowo Village both historically and existing; the weaknesses and advantages of each energy source; as well as seeing how the community's interest in the development of renewable energy sources in the future.

Primary data is obtained through direct observation as well as interviews with the Medowo Village community, stakeholders, and energy planning experts. Secondary data is obtained through literature studies or data that is already available both in Medowo Village and government agencies related to this research. The need for primary and secondary data in this study is shown in the following table.

Table 1.List of Primary Data

Data	Data Source
Cooking fuel dan daily or monthly energy consumption Historical data of RE usage	Questionnaire and interviews with the Medowo Village community

Table 2. List of Secondary Data

Data	Data Source
Medowo Village population data	Civil Registration Office of Kediri Regency
Number of digester owners, funding, and capacity	KUD Kertajaya

Determining the Number of Respondents

The sampling technique used for qualitative research is purposive sampling. According to Sugiyono (2020), the purposive sampling technique is a sampling determination technique based on certain considerations. In this study, household respondents from the Medowo Village community were selected based on the following considerations: having used or currently using one or more renewable energy conversion technologies (biogas, microhydro, and/or rooftop PV); and only 1 respondent per households.

Based on data from the Kediri Regency Population and Civil Registry Service, in 2022 there were 1,373 households in Medowo Village. And according to KUD Kertajaya, in 2022 there were 262 dairy farmers households of which 225 households had biogas digesters and 37 who did not. Overall in Medowo Village there are 300 biogas installations. One dairy farm household can have more than 1 biogas digester. Microhydro and rooftop PV users are also included in these 225 households. The other 37 households that did not use biogas were involved in the study to determine the differences in energy use between the two types of households. Therefore, by conducting purposive sampling, the number of respondents used was 262 households.

Current Biogas Production

The biogas production capacity of a digester can be estimated by using the reference quantity and type of raw materials used. IRENA (2016) estimate the biogas production produced by the available digesters by using the following equation 1.

$$G = \frac{Y \times V_d \times S}{1000} \quad (1)$$

Where, G is the biogas production in m^3/day; Y is yield factor; V_d is the digester volume with units of m^3; and S is the initial volatile solids concentration in the slurry with units of kg/m^3. The value of S is obtained by dividing the weight of volatile solid (kg/day) by the daily manure input. Daily manure input is the volume of all manure plus the volume of water added for dilution. Table 4 below shows the yield factors (Y) values for each temperature range and retention time.

Table 3. Yield Factor for Biogas Production (Irena, 2016)

Retention time	Temperature (°C)					
(days)	16-18	19-21	22-24	25-27	28-30	31-33
6-10	5.41	7.98	10.83	13.59	15.91	18.33
11-15	4.73	6.79	8.99	11.09	12.88	14.74
16-20	4.21	5.90	7.68	9.37	10.82	12.32
21-25	3.79	5.22	6.70	8.11	9.33	10.59
26-30	3.44	4.69	5.95	7.15	8.20	9.28
31-35	3.16	4.25	5.35	6.39	7.32	8.26
36-40	2.91	3.88	4.86	5.78	6.60	7.44
41-45	2.71	3.58	4.45	5.27	6.02	6.77
46-50	2.53	3.32	4.10	4.85	5.53	6.21
51-55	2.37	3.09	3.81	4.49	5.11	5.74
56-60	2.23	2.89	3.55	4.18	4.75	5.33
61-65	2.10	2.72	3.33	3.91	4.44	4.98
66-70	1.99	2.57	3.13	3.67	4.17	4.67
71-75	1.89	2.43	2.95	3.46	3.93	4.40
76-80	1.80	2.30	2.80	3.27	3.71	4.15
81-85	1.72	2.19	2.66	3.10	3.52	3.94
86-90	1.65	2.09	2.53	2.95	3.34	3.74
91-95	1.58	2.00	2.41	2.81	3.19	3.56
96-100	1.52	1.92	2.31	2.69	3.04	3.40

Theoritical Biogas Potential

In practice, the digester capacity owned by farmers is not proportional to the number of livestock owned. The average number of cattle in Medowo Village is 5 to 6 cows per household. According to SNI 7826-2012, a fixed dome type digester tank made of concrete ideally has a capacity of 12 m3 for farm with 6 cows (Badan Standardisasi Nasional, 2012; Irena, 2016). Meanwhile, the digester that is most widely used in Medowo Village is 4 m3 and 6 m3. Thus, the potential biogas that can be produced by Medowo Village is actually greater than the capacity of the digester used. The potential biogas produced for each type of livestock is the result of an estimate using the equation (Khalil et al., 2019) as follows,

$$TPB = M \times TS \times AC \times EB_{TS} \quad (2)$$

TPB is the theoretical biogas production potential (m^3/year); M is the total livestock manure production (kg/year); TS is the total solid ratio of livestock manure; AC is the availability coefficient; and EB_{TS} is the estimated biogas produced from each kg of livestock manure ($m^3kg^{-1}TS$). According to Khalil et al. (2019) for large and small ruminants the TS value is 25%, while the AC value is 50% for large ruminants and 13% for small ruminants. Meanwhile, the EB_{TS} value is set at 0.3 m^3 per kg of livestock manure, assuming that all livestock manure is used for biogas production and there is no weight loss due to evaporation. Thus, for dairy cattle, equation (3) above can be rewritten as follows,

$$TPB = M \times 25\% \times 50\% \times 0,3 \quad (3)$$

In this study, TPB was used to see the potential for increasing biogas production which could be done to increase the portion of renewable energy in the total energy mix of Medowo Village.

Energy Demand

Energy use in rural areas is generally electricity and cooking fuel. The types of energy sources used were obtained from observations and interviews. According to Alqurni et al. (2023) the energy demand of the rural sector are calculated using the following useful energy analysis equation,

$$E = A \times U / Eff \quad (4)$$

Where E is the energy requirement, A is the energy usage activity, U is the intensity of useful energy usage, and Eff is the efficiency (%). Useful energy in rural areas dominated by household activities includes cooking, refrigeration, lighting, thermal comfort (AC or fan), television, and so on (Adiarso et al., 2020). Activities and energy use useful for cooking was obtained from questionnaire represented by questions regarding the number of family members, type and amount of energy sources used in a 1-month period, and duration of cooking activities. Data for electricity usage are the type and number of electrical appliances, the operating hours and duration of use of the equipment.

Energy Independent Village Assessment

From the results of the analysis of energy demand and renewable energy production (biogas), the percentage of renewable energy contribution in the total energy mix is then calculated, so that it can be known whether Medowo Village has achieved energy independence or not.

Result and Discussion

Current Biogas Production

Based on data from KUD Kertajaya, the development of the first biogas digester in Medowo Village was initiated in 2006 through a collaboration between Hivos and the Ministry of Energy and Mineral Resources. Hivos also provides subsidies to families interested in building a biogas digester. KUD Kertajaya as a dairy cooperative institution that has already served Medowo Village issued a credit product which was later known as "Biogas Credit", a financing program for dairy farmers who want to build a biogas digester. KUD Kertajaya helps build digesters and biogas stoves. The construction costs can be paid in installments. In 2010, the Medowo Village community also received a subsidy for the construction of a biogas digester from PT. Nestle's CSR funds.

From the cooperation with various institutions, the Medowo Village community gained basic knowledge about the design, procedures for use and maintenance of biogas digesters, as well as biogas lamps and stoves. Because this village has a 100% electrification ratio, biogas lamps are no longer used. Biogas now only serve as fuel for stoves used for cooking daily food.

Table 4. Construction Costs of 6 m^3 Capacity Biogas

Year	Construction costs (IDR)	Subsidy (IDR)	Subsidy source
2006	6 million	2 million	Hivos
2010	9 million	2 million	Hivos
		2 million	PT Nestle
2017	11 million	1 million	Hivos
		4 million	PT Nestle

The larger the digester capacity, the more animal manure input will be required, higher installation costs, and a larger area of land. The digester design in Medowo Village uses a fixed dome digester type and is a modification of the Hivos digester design which was previously intended for pig farming. In its implementation, the people of Medowo Village mostly use a digester design with a capacity of 6 m^3 which can also be seen from the results of the questionnaire where 78.08% respondents used this design. The capacity of 6 m^3 was chosen because most households in Medowo Village consist of 4 to 5 people. So the digester capacity is considered sufficient to serve the energy needs for daily cooking activities. Figure 2 below is the design of a 6 m^3 biogas digester that is most often used in Medowo Village.

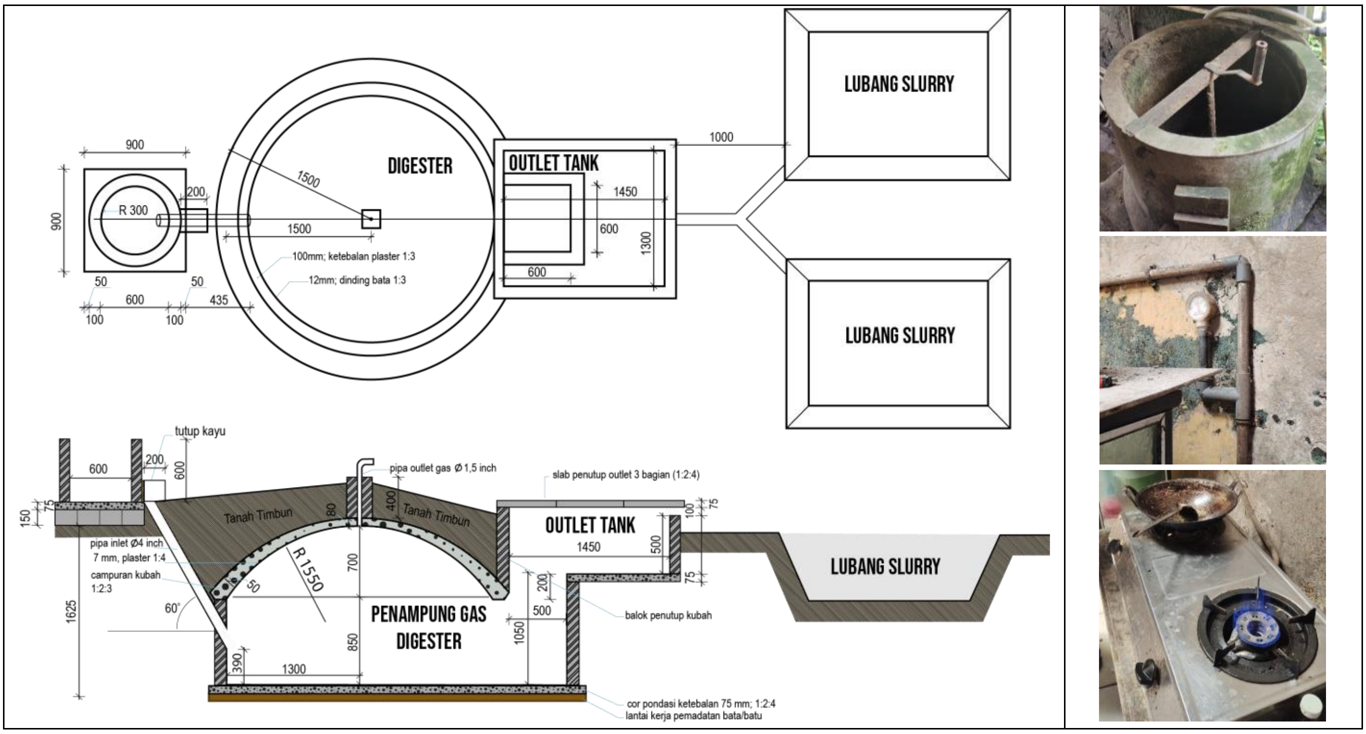

Figure 2. Biogas digester in Medowo Village

For a capacity of 6 m³, after the digester is completed, during the initial filling, farmers must put in around 2400 kg of cow dung mixed with water in a ratio of 1:1. To accelerate gas formation, slurry from biogas that has been produced as much as 50-60 kg is also added as a microbial starter. Then the filling of the digester is stopped temporarily until gas is formed. The time required for this gas formation is called the retention time. Based on empirical data from KUD Kertajaya, in general the retention time of the digester in Medowo Village is around 50 days. According to Suyitno et al. (2010), since the average temperature in Indonesia is stable throughout the year, the retention time (R) for a simple biodigester without a heater is considered constant. Based on Irena (2016), the average temperature in biogas production in Indonesia is 26°C. For digesters built in the ground, 2°C must be added to obtain the digester temperature (Irena, 2016); Suyitno et al. (2010). So with a retention time of 50 days and a digester temperature of ± 28°C, the yield factor used is 5.53. After gas is formed, the next step is to fill the manure every day with varying amounts depending on the digester capacity. According to Abdallah et al. (2018), the manure produced by adult dairy cows in lactation conditions is 25 kg/day. Thus, the initial input, daily input, and minimum number of livestock to meet the needs of each digester size are shown in table 5 below. Using equation (1), the calculation in Table 6 is obtained with the number of digesters as many as 300 units, the biogas production of Medowo Village is 131,690.73 m³/year.

Table 5. Initial Input and Daily Input of Cow Manure (Irena, 2016)

Digester capacity (m³)	Initial manure input (kg)	Daily manure input (kg)	Number of cows	Volatile Solid (kg/day)
4	1600	32	2	
6	2400	48	3	
8	3200	64	4	1.42
10	4000	80	5	
12	4800	96	6	

Table 6. Biogas Production of Medowo Village in 2022

Digester Capacity (m³)	Daily biogas production (m³/day)	Number of digester	Annual biogas production (m³/year)
4	0.81	52	15 467.87
6	1.22	234	104 408.15
10	2.04	5	3 485.85
12	2.44	8	7 139.02
16	3.26	1	1 189.84
Annual biogas production (m³/year)			131 690.73

Theoretical Biogas Production Potential

In practice, the potential biogas that can be produced by Medowo Village is actually greater than the capacity of the digester used. In this case, calculations are made on the theoretical biogas production potential to determine how much increase in biogas production can be achieved. Biogas production using livestock manure as raw material is highly dependent on the volume of manure produced by each livestock each day (Indrawan et al., 2018). For dairy cows, the amount of manure produced is correlated with the cow's ability to produce milk. Adult female dairy cows in productive or lactating conditions will consume more feed to produce milk. Thus, they will produce more manure per day. Meanwhile, calves will consume less feed than their mothers and will produce less manure. To determine the potential for biogas production in Medowo Village as a whole, equation (3) is used. Data on the number of farmers and the population of dairy cows in Medowo Village were obtained from KUD Kertajaya. Annual cow manure production (M) is the result of multiplying daily cow manure production (kg/day) by the number of days in the year. Manure production for each dairy cow growth stage using values generated from Abdallah et al. (2018) research as shown in Table 8. In this study, adult dairy cows in lactation stage are included in the high category; non lactating adult dairy cows and bulls are included in the dry category; empty and pregnant heifers are included in the fresh category; and dairy calves are included in the young category. Based on the data in Table 8 and 9, the theoretical biogas potential in Medowo Village fluctuates along with the development of the dairy cattle population. In the period 2017 to 2022, the largest biogas potential was in 2020, reaching 346,007.25 m^3/year. While in 2022 the production potential reached 326,679.56 m^3/year. Thus, in 2022 the volume of biogas utilized by Medowo Village only reach 40.31% of the theoretical biogas production potential.

Table 7. Manure Generated by Dairy Farm

Growth Stage	Manure generation (kg/cows)
High	25
Dry	5
Fresh	8
Young-1	4
Young-2	4

Table 8. Number of Farmers (People), Dairy Cattle Population (Head), M (kg/year) and TPB (m^3/year) 2017-2019

Category			2017			2018			2019
	P (cows)	M	TPB_{2017}	P (cows)	M	TPB_{2018}	P (cows)	M	TPB_{2019}
Number of Dairy farmers	315			225			269		
Cow Adult									
a. High - Lactating	383	3 494 875	131 057.81	175	1 596 875	59 882.81	456	4 161 000	156 037.50
b. High - pregnant	203	1 852 375	69 464.06	395	3 604 375	135 164.06	219	1 998 375	74 939.06
c. Dry	85	155 125	5 817.19	87	158 775	5 954.06	120	219 000	8 212.50
d. Bulls	0	-	-	0	-	-	0	-	-
Cow Heifer									
a. Fresh	69	201 480	7 555.50	76	221 920	8 322.00	97	283 240	10 621.50
b. Pregnant	94	274 480	10 293.00	63	183 960	6 898.50	100	292 000	10 950.00
Cow Calf									
a. Heifer	174	254 040	9 526.50	144	210 240	7 884.00	176	256 960	9 636.00
b. Bull	0	-	-	74	108 040	4 051.50	0	-	-
otal	1 008	6 232 375	233 714.06	1 014	6 084 185	228 156.94	1 168	7 210 575	270 396.56

Table 9. Number of Farmers (People), Dairy Cattle Population (Head), M (kg/year) and TPB (m^3/year) 2020-2022

Category		2020*			2021				2022
	P (cows)	M	TPB_{2020}	P (cows)	M	TPB_{2021}	P (cows)	M	TPB_{2022}
Dairy farmers	455			252			262		
Cow Adult									
a. High - Lactating	644	5 892 600	220 972.50	536	4 891 000	183 412.50	507	4 626 375	173 489.06
b. High - pregnant	240	2 196 000	82 350.00	243	2 217 375	83 151.56	291	2 655 375	99 576.56
c. Dry	102	186 660	6 999.75	87	158 775	5 954.06	130	237 250	8 896.88
d. Bulls	0	-	-	18	32 850	1 231.88	7	12 775	479.06
Cow Heifer									
a. Fresh	132	386 496	14 493.60	122	356 240	13 359.00	118	344 560	12 921.00
b. Pregnant	97	284 016	10 650.60	113	329 960	12 373.50	109	318 280	11 935.50
Cow Calf									
a. Heifer	192	281 088	10 540.80	194	283 240	10 621.50	230	335 800	12 592.50
b. Bull	0	-	-	103	150 380	5 639.25	124	181 040	6 789.00
Total	1 407	9 226 860	346 007.25	1 416	8 419 820	315 743.25	1 516	8 711 455	326 679.56

* 2020 is leap year so the number of days in 2020 is 366 days.

Energy Demand : Cooking Fuel

Based on the results of interviews and questionnaires distributed to respondents, the energy sources used for cooking in Medowo Village include biogas, fuel wood, LPG, and electricity. The use of biogas, fuel wood, and LPG are interchangeable, while electricity is only used for rice cooking and keeping it warm. As many as 67.21% of respondents use electricity to cook, while 32.79% cook rice using a stove. All respondents who use electricity for cooking are electricity users in the R-1/TR group with a power of 450 VA and 900 VA. Based on PLN (2024), the basic electricity tariff for this group is IDR 1,352/kWh. So in a year the average household spends 317,55 kWh/year or Rp 426,914.36 worth of electricity for cooking activities.

Table 10. Electricity Consumption for Rice Cooking

Cooking Process	(kW)	(hour/day)	(kWh/day)
Cook	0.38	1	0.38
Warm	0.09	6.56	0.59
Avg. Electricity Consumption (kWh/day)			0.87
(kWh/year)			317.55
Electricity Expense for cooking (IDR/day)			Rp 1,169.63
(IDR/month)			Rp 35,088.85
(IDR/year)			Rp426,914.36

Biogas production from each digester is sometimes not enough for daily cooking needs so that biogas households still provide LPG as a reserve. Thus, it is assumed that the use of biogas in a year is the same as the total biogas production produced in a year. With a total production of 131,690.73 m^3 per year, the average use of biogas from 225 biogas households is 585.29 m^3/year or equivalent to 48.77 m^3/month.

There are 4 (four) types of biogas households based on the energy sources used, namely household type 1 using biogas; household type 2 using biogas and LPG; household type 3 using biogas and fuelwood; and household type 4 using biogas, LPG, and fuelwood. In this study, the percentage of biogas households type (1) was 20.34%; type (2) was 35.59%; type (3) was 13.56%; and type (4) was 30.51%. In households with several types of fuel, biogas is still used as the main fuel for cooking while other fuels are used as reserves. LPG is used as an energy reserve for daily cooking activities, while firewood is used entirely as an energy source for dairy farm activities.

Based on the data in table 11, for type (2) household it is clear that the smaller the digester capacity owned, the greater the intensity of LPG use. Owners of digesters with a capacity of 4 m^3 have an intensity of use of 3kg LPG type of 3.40 cylinders per month and for the type of digester 6 m^3, the intensity of LPG use is 1.92 cylinders per month. While for the type of digester more than 10 m^3, LPG is really only used when needed for cooking in large quantities. Type (3) household is divided into 2 (two) more, namely those with digesters ≤ 6 m^3 and those with digesters > 6 m^3. Owners of digesters under 6 m^3 use biogas to cook daily food and fuelwood to supports livestock activities. Although used in separate processes, there is still a correlation between digester capacity and the intensity of fuelwood use. Because it is used to heat water for dairy farm activities, the amount of firewood used is directly correlated with the number of livestock owned. Owners of digesters with a capacity of 6 m^3 generally have more livestock than owners of digesters with a capacity of 4 m^3. So the use of firewood by 6 m^3 digester households is greater than that of owners of 4 m^3 digesters. For type (3) household with above-6m^3-digester, biogas is used both for cooking and for dairy farm activities, while firewood is used as supporting fuel. Therefore, in household with a 12 m^3 digester, the intensity of firewood use decreases to 0.5 m^3/month, lower than the intensity of firewood use by owners of a 6 m^3 digester, which is 0.87 m^3/month.

Table 11. Comparison of Biogas-Based-Household Energy Consumption in Desa Medowo

Digester capacity (m^3)	(1) biogas		(2) biogas + LPG			(3) Biogas + fire wood			(4) biogas + fire wood + LPG			
	n	Biogas	n	Biogas	LPG	n	Biogas	wood	n	Biogas	LPG	wood
4	2	0.81	11	0.81	3.40	2	0.81	0.50	6	0.81	1.00	0.50
6	24	1.22	33	1.22	1.92	15	1.22	0.87	37	1.22	1.92	1.08
10	0	2.04	2	2.04	1.00	0	2.04		0	2.04		
12	3	2.44	9	2.44	1.00	3	2.44	0.50	0	2.44		
16	0	3.26	0	3.26	0	0	3.26		1	3.26	3.00	1.00
- biogas consumption (m^3/day)		1.34		1.44			1.34			1.20		
- LPG usage intensity 3 kg cylinder/month					2.15						1.80	
- fire wood usage intensity(m^3/month)								0.77				0.99

In type (4) household, the energy source used for cooking is a combination of biogas, fuelwood, and LPG. The selection of the type of energy used for cooking in this household type is more complex than the previous 3 household types. Like the previous types, biogas is the main fuel for cooking while LPG is used as a reserve. However, most of the households included in type (4) are dairy farmers who are most affected by the foot-and-mouth disease outbreak that attacked cattle that occurred in 2022. The Kediri District Animal Husbandry Service stated that Kandangan District was the first area where reports of this disease were found (Diskominfo

Kabupaten Kediri, 2022). As a result, dairy farmers reduced the number of livestock and thus there was a decrease in biogas production. In addition to the problem of disease outbreaks, the dairy cows owned are entering the dry phase or are not lactating so they produce less manure. Based on KUD Kertajaya data, the number of cows entering the dry phase in 2022 was 130 cows or an increase of 43 cows from the previous year. Khalil et al. (2019) stated that cows in the high or lactation phase produce 25 kg of manure per day while cows in the dry phase produce 5 kg per day. Therefore, the use of LPG has increased in this group. In the type (4) household there is also a 16 m^3 digester. This digester is the largest household-scale digester in Medowo Village. This digester is used together by 3 families, so to meet the energy needs for cooking, the intensity of LPG use is still quite high every month.

Table 12. Cooking Fuel Expense of Medowo Village households

No	Cooking Fuel	(1) biogas	(2) biogas + LPG	(3) biogas + fire wood	(4) biogas + fire wood + LPG	(5) LPG + fire wood	(6) LPG
Number of households		12	21	8	18	37	1111
A	Biogas (m^3/hari)	1,29	1.63	1.32	1.29	-	-
	(m^3/tahun)	470,98	594.92	483.37	470.98	-	-
	A expense (Rp/year)	-	-	-	-	-	-
B	LPG (3 kg cylinder/month)	-	2.42	-	1.88	4.00	4,00
	(3 kg cylinder/year)	-	29.05	-	22.56	48.00	48,00
	B expense (Rp/year)	-	552,043.96	-	428,717.95	912,000.00	912.000,00
C	Firewood (m^3/month)	-	-	0.78	1.01	0.78	-
	(m^3/year)	-	-	9.30	12.17	9.30	-
	C Expense (Rp/year)	-	-	262,392.86	343,273.81	262,392.86	-
Total Expense (A+B+C) (Rp/households/year)		-	552,043.96	262,392.86	771,991.76	1,174,392.86	912.000,00

In addition to the 4 types of biogas households, based on data from KUD Kertajaya, there are still 37 dairy farm households that did not have biogas digester. The types of fuel used for cooking activities are LPG and firewood. LPG is used for cooking while firewood is used for heating water in dairy farming activities. The type of non-dairy farm household generally uses LPG to cook food. The number of this type of household is around 1,111 households. Based on the results of the interview, in general the type of non-biogas household in Medowo Village consumes 4 LPG-cylinders every month. Thus, overall, in Medowo Village there are 6 types of households based on the type of energy used, namely type (1) biogas; type (2) biogas and LPG; type (3) biogas and fuelwood; type (4) biogas, LPG, and fuelwood; type (5) LPG and firewood; and type (6) LPG. Households that fully use LPG are generally non-dairy farming households. Based on the questionnaire, a 3kg-LPG-cylinder is sold at an average price of Rp 19,000 in Medowo Village and the price of firewood per cubic meter is an average of Rp 28,214. As for biogas, after the digester is able to produce biogas, the digester owner does not spend money to buy energy sources for cooking every month. Biogas-based households have lower energy expenditure than those using LPG. Based on table 13, type (1) household spends Rp0/year for cooking fuel. If type (1) household uses electricity to cook rice, then the energy expenditure is the same as the electricity expenditure for cooking in table 11, which is Rp 426,914.36/year.

Energy Demand : Electricity

In 2023, the electrification ratio of Medowo Village is 100%. This means that all houses in the Medowo Village area are connected to PLN grid. The results of data processing for electricity usage are shown in Table 13. The types of electronic equipment most commonly owned by the population are LED lights (100%); TV (86.89%); Iron (75.41%); Refrigerator (62.30%); and washing machine (54.10%). The electronic equipment that consumes the most electricity is the refrigerator, which reaches 3,489,598.41 MJ/year or reaches 52.72% of total energy usage. This is because refrigerators generally operate continuously for 24 hours to keep food and drinks from spoiling. The next is energy for lighting with a portion of 18.44% and TV which contributes 12.93%. Overall, the operation of electronic equipment is estimated to consume 6,618,503.90 MJ of energy per year.

Energy Independence Assesement of Medowo Village

To determine the level of independence in providing energy for Medowo Village, it is necessary to compare the value of energy demand for cooking and electricity to the contribution of biogas and firewood in the energy mix of Medowo Village.

Table 13. Household Electricity Usage (Does Not Include Cooking)

Loads	Power (Watt)	Average number of Units	Operational hours (hours/day)	Electricity Consumption (kWh/day)	Annual Electricity Consumption (kWh/year)	Households (percent)	Number of Households (2022)	Energy Consumption (MJ/year)
LED lamps	15.62	5.98	7.24	0.68	246.92	100.00%	1,373	1,220,457.56,
Water Pump	157.86	1.14	1.14	0.21	75.26	11.48%		42,702.76,
TV	106.70	1.11	4.59	0.55	199.18	86.89%		855,444.18,
Computer	212.00	1.20	1.70	0.43	157.86	8.20%		63,980.23,
Refrigerator	133.76	1.00	23.21	3.10	1,133.22	62.30%		3,489,598.41,
Fan	58.08	1.46	3.31	0.28	102.48	21.31%		107,941.46,
Iron	317.72	1.00	0.76	0.24	88.30	75.41%		329,110.23,
Washing machine	256.52	1.00	1.93	0.49	180.64	54.10%		483,030.29,
Milking machine	500.00	1.00	1.33	0.30	107.90	4.92%		26,238.78,
Total Electricity Consumption					2,295.42			6,618,503.90

Table 14. Energy Equivalencies of Biogas with Commonly Used Fuel (Irena, 2016)

Fuel Combustion	Equivalent to combustion of m3 biogas	
	Unadjusted	Adjusted
1 kg fuelwood	0.70	0.25
1 kg charcoal	1.40	0.65
1 liter kerosene	1.60	1.60
1 liter LPG	1.05	1.05
1 kg LPG	2.10	2.10

Table 14 is the equivalence of biogas with how many types of fuel are often used. The average methane production in biogas is around 65% and every 1 m^3 of methane gas burned will produce 34 MJ of energy (Silaen et al., 2020). Therefore, 1 m^3 of biogas can produce 22 MJ of energy. Equivalencies adjustment is carried out because the stoves used for each type of fuel have different efficiencies.

The fuelwood used in Medowo Village is in the form of logging residue such as pieces of branches, twigs, and bark of sengon trees from community forest activities around the village. The villagers can also collect dry branches and twigs from the forest. The calorific value produced by dry twigs and twigs collected by residents varies depending on the size of the twigs and the composition of the types of trees used. Therefore, in this study, the estimation of fuelwood consumption uses logging residue in the form of pieces of branches and bark from the same tree species in one pile. Firewood is sold in cubic meters. So to convert volume units (m^3) to weight units (kg), it is necessary to first know the density of the type of wood used. Sulistyo et al. (2021) stated that the density of sengon tree logging residue in the form of bark and wood is in the range of 0.383 - 0.592 g/cm^3. In this study, the mean value was used so that the density of sengon mining waste is 0.4875 g/cm^3. Biogas and fuelwood used by all biogas households in a year contribute 2,897,196.16 MJ/year of energy.

Table 15. Energy mix of Medowo Village

Energy Sources	Energy Intensity per household		Village Energy Consumption (MJ)	Percent in Energy Mix (%)
	MJ	Equal to		
Electricity	8,470.92	1,581,55 kWh/year	7,817,270.61	41.47%
Biogas	12,876.43	585,29 m^3/year	2,897,196.16	15.37%
LPG	6,269.61	42,72 cylinder/year	8,129,977.71	43.13%
Firewood	28.28	10,55 m^3/year	3,850.98	0.02%
Total			18,848,295.46	100.00%

Medowo Village energy mix is a combination of energy consumption for cooking activities and electronic equipment operation. The portion of biogas and firewood, which are included in the renewable energy category, only reached 15.39% of the total energy use of Medowo Village. This shows that Medowo Village has not yet achieved energy independence.

To achieve energy independence, it is recommended to increase the number of digesters. Not only dairy farm owners, biogas digesters can also be built by non-dairy farm households. Because the daily cow manure produced is more than the daily input of digester, other residents can buy excess cow manure from the farmer. The cow manure is sold at a very low price, around IDR 1000 per 25 liter, so in a month the cooking fuel expense is around IDR 30,000 which is way lower than energy expense of LPG. This has been implemented by several households, but even though the price is cheap, the uptake of biogas technology for non-dairy-farm-households in Medowo Village is still relatively low.

Based on the results of the questionnaire and interviews, the problem faced in the use of biogas is the limited land used to build a digester. Medowo Village has contoured land and most houses are built on the side of a hill so that not all houses can build a digester. This can be overcome by building a digester communally which is then utilized by several houses as done by the owner of a 16 m3 digester. Houses without cattle farms can pay the cost of connecting the pipes and a monthly subscription fee to the digester owner. In addition to the problem of limited land, parts of the biogas installation such as pipes, taps, and stoves are also often damaged because biogas contains hydrogen sulfide (H_2S) (Dada et al., 2025). H_2S gas when burned produces sulfur dioxide (SO_2) which is corrosive (Das et al., 2022; Paz et al., 2025). Therefore, the biogas stove in Medowo Village only lasts 2-3 years and then has to be replaced because the gas line is corroded and leaking. The solution to the problem has to be simple, as cheap as possible, and can be easily obtained from the surrounding environment because household-scale biogas digesters generally do not have a large capital capacity such as by adding activated carbon from coconut charcoal (Su et al., 2021), adding chopped rice straw to the slurry (Barata et al., 2024), or adding biofilter (Ningsih et al., 2024; Valenzuela-Heredia & Aroca, 2023; Yellezuome et al., 2022).

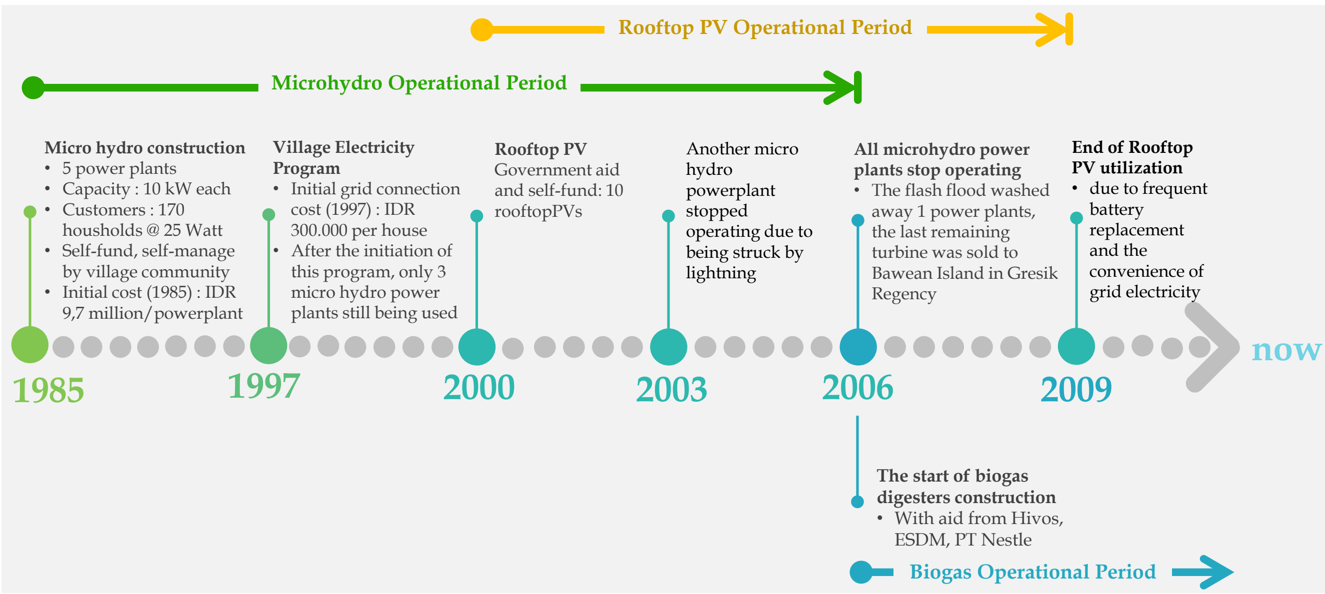

Figure 3. Timeline of renewable energy usage in Medowo Village

In addition to increasing the number of digesters, it is necessary to diversify energy sources. The use of electrical energy is almost as large as the energy for cooking, reaching 41.47% in the energy mix of Medowo Village, so alternative sources of electrical energy can be sought other than PLN. Based on the results of the interview, Medowo Village has also utilized microhydro and rooftop PV. Figure 3 is a timeline of renewable energy utilization by Medowo Village. Although there is potential for utilizing other renewable energy besides biogas, the urgency to reactivate microhydro and rooftop PV in Medowo Village is still low because the electrification ratio of Medowo Village reaches 100%. The PLN electricity network is considered much more stable and practical. In addition, the discharge of the Seloateb River, which is a source of microhydro water, continues to experience a decrease in discharge from year to year due to changes in land use from rice fields and forests to elephant grass fields used for animal feed. Cow dung waste that is not completely absorbed for biogas production is mostly discharged into river water bodies and further reduces the quality of river water. Meanwhile, for rooftop PV, the low public interest is due to the expensive installation costs and require understanding in sophisticated technology.

In response to the various challenges that exist, the problem of increasing energy independence in Medowo Village cannot be solved by the community alone. The role of the government is also crucial in efforts to achieve energy independence in the village (Silaen et al., 2020; Subagiyo et al., 2020). First, a good evaluation instrument is needed so that the progress of the development of energy independent villages can be evaluated in a measurable manner. The government needs to determine the predicate or classes of villages according to the percentage of renewable energy in the total energy mix. A threshold of 60% is indeed needed, but predicates per progress of increasing the use of renewable energy sources are still needed. To increase community motivation, incentives can be given along with the increase in the predicate of village energy independence (Pramadya & Kim, 2024).

Conclusion

Biogas energy potential of Medowo Village is 326, Biogas and firewood only contribute 15.39% to the total energy mix. This means that Medowo Village has not fully achieved energy independence. There is a possibility to increase the portion of biogas in the village energy mix considering that only 40.31% of the biogas potential has been utilized. In addition to biogas, diversification of other energy sources such as solar and microhydro can also be considered. An evaluation instrument for the progress of developing an energy independent village can be prepared to provide justification for technology transfer, funding subsidies, and incentives.

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Wijayanti contributed to research, data analysis, and article writing; while Surjono and Kartikaningsih as supervisor in research until completion of article writing.

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